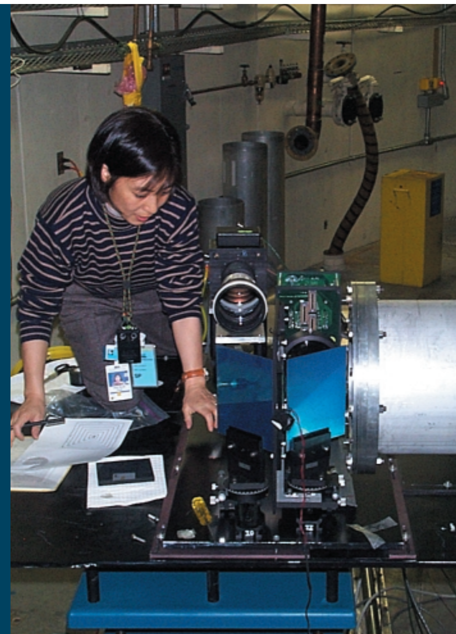
Decisions and actions about the stockpile must be grounded in experimental reality. In the past, that reality included nuclear testing. Now, we ensure stockpile performance using laboratory experiments and computer modeling to achieve a much more sophisticated understanding of the underlying physics and engineering issues.



A Livermore physicist checks an imaging station and Laboratory-designed detectors at the end of the proton beamline at the Los Alamos Neutron Science Center. Together with Los Alamos scientists, we are exploring the possibility of using protons instead of x rays to create radiographic images for studies of nuclear weapons.

Stockpile Stewardship—Modeling and Experiments

At Livermore, this two-stage gas gun accelerates projectiles to speeds of 8 kilometers per second to produce in a target a shock wave that is millions of times atmospheric pressure. We are bringing the Joint Actinide Shock Physics Experimental Research (JASPER) Facility into operation at the Nevada Test Site. With JASPER, researchers will perform important gas-gun experiments using uranium and plutonium targets.

Subcritical Experiments Study Plutonium

We successfully completed six of the eight planned subcritical experiments that compose the Oboe series, including four tests in 2000. Conducted in an underground tunnel at the Nevada Test Site, these highly instrumented experiments provide data on the behavior of plutonium when it is strongly shocked and how that behavior differs depending on the plutonium's age. These tests, which complement simulations and laboratory experiments, help us understand how aging-related changes in plutonium affect the performance of stockpiled weapons.

Because we want to achieve test conditions, high explosives are detonated next to samples of plutonium. No critical mass is formed in the process, so no nuclear fission chain reaction occurs as it would in a nuclear detonation. Tests are instrumented with high-speed diagnostics, including a laser-based system that obtains holographic images of plutonium ejecta flying out from the shocked surface at the moment of explosion. The film images, when projected with a laser, allow experimenters to see in 3D a cloud of plutonium and analyze the size, shape, and velocity of the particles.

The Oboe tests are the first to be performed inside individual confinement vessels. Personnel enter the underground test chamber to retrieve films and data after the test, once the chamber is determined to be free of contamination. The use of vessels for subcritical experiments is significantly reducing costs. Previously, each subcritical experiment took a minimum of one year to field and rendered unusable all diagnostic equipment in the test chamber.

A Better Model of High-Explosive Detonation

By linking two previously separate physics models, Livermore scientists now have a much better capability to simulate the detonation of high explosives. One of the codes, CHEETAH, models the chemical kinetics and thermodynamics involved in a detonation. Developed at the Laboratory with support from both DOE and DoD, CHEETAH is widely used within the defense community to evaluate new high explosives. CHEETAH is

Equipment typically used for making subway tunnels (left) carves out Livermore's underground test facilities. In a finished alcove (right), Livermore and Bechtel Nevada workers lower a package of plutonium and explosives into the heavily instrumented containment vessel for an Oboe subcritical experiment.

linked to the ARES hydrodynamics code. In the resultant simulation, as ARES determines the motion of the materials, CHEETAH provides at each time step the state of chemical reactions and equation-of-state data for the relevant intermediate and reaction products, which affect subsequent hydrodynamic performance.

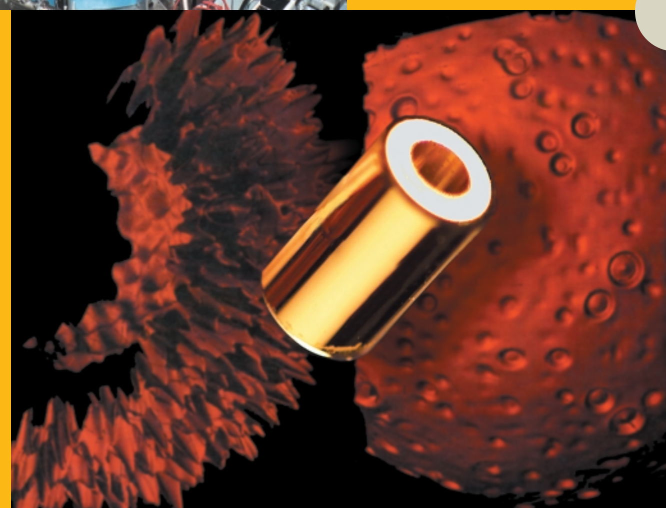
Better data increase the accuracy of the simulation models. Experiments are being performed to obtain improved equation-of-state data for the materials—such as carbon dioxide—produced by high-explosives detonation. Researchers used Livermore's diamond anvil cell to study carbon dioxide at extreme conditions and, in the process, created two forms of solid carbon dioxide never seen before in the laboratory.

3D Weapons Physics Simulations

Increasingly sophisticated 3D simulations of weapons physics are being made possible by successively more powerful computers, which have been installed at the Laboratory as part of the DOE's Accelerated Strategic Computing Initiative. Three-dimensional simulation is critically important: nuclear explosion phenomena are seldom symmetric because of aging and manufacturing variations.

Livermore researchers achieved a major milestone in the Stockpile Stewardship Program in late 1999 with the first-ever 3D simulation of a nuclear-weapon primary explosion. The next step in the full-system modeling of weapon performance is a 3D simulation of the thermonuclear burn of a weapon secondary. Such work is in progress using the ASCI White supercomputer.

In addition to the codes developed to simulate nuclear weapon performance, the Laboratory has developed the HYDRA code, which was used in 2000 to simulate in 3D the performance of targets that might be used in the National Ignition Facility to achieve ignition and thermonuclear burn. The simulations were run on 1,680 processors of the Blue Pacific computer using a mesh of more than 16 million zones. HYDRA was also used to model the results of hydrodynamic instability experiments performed on the Laboratory's Nova laser and the University of Rochester's Omega laser.



In a 3D HYDRA simulation using over 16 million zones, we studied the growth of hydrodynamic instabilities due to surface roughness in a target capsule for the National Ignition Facility. Two surfaces of constant density (left) are shown prior to thermonuclear ignition; a contour of the rebounding shock at ignition time is on the right. A typical NIF capsule is shown in the foreground.